higher roots is given. The earlier roots are examined numerically, and tabulated for four different depths of the ocean for the types involving tesseral harmonics of rank 1 and 2, these types presenting special interest in connection with the diurnal and semi-diurnal forced tides respectively.

The types of free oscillation are found to be of two classes, distinguishable by their limiting forms when the rotation-period is indefinitely prolonged. In the former class the motion remains oscillatory when the period of rotation becomes infinitely long, while in the latter the "speed" of the oscillation always bears a finite ratio to the angular velocity of rotation, so that the oscillation will be replaced by a steady motion when the angular velocity of rotation is reduced to zero.

In dealing with the forced oscillations, the theorem of Laplace that in an ocean of uniform depth there will be no diurnal rise and fall at the surface is obtained and generalised as follows:—In an ocean of uniform depth the tides due to a disturbing potential of degree $s+1$ and rank s will involve no rise and fall at the surface if the period of the disturbing force be $\frac{1}{2}(s+1)$ sidereal days.

A theorem given by Professor Darwin with reference to the expression of the semi-diurnal tides in finite terms, as also Laplace's solution of the problem of the diurnal tides in an ocean of variable depth, is found to admit of similar generalisation.

The general problem of the forced tides due to any disturbing force derivable from a potential function in the cases where infinite series are required for the solution is treated analytically, and is further illustrated by numerical examples typical of the leading tidal constituents which occur on the earth, the results where possible being compared with those obtained by other methods.

"On Methods of making Magnets independent of Changes of Temperature; and some Experiments upon Abnormal or Negative Temperature Coefficients in Magnets." By J. REGINALD ASHWORTH, B.Sc. Communicated by ARTHUR SCHUSTER, F.R.S. Received October 29,—Read December 9, 1897.

The present investigation, which has been carried out in the Physical Laboratory of the Owens College, Manchester, was undertaken at Professor Schuster's suggestion with the object of ascertaining what kinds of iron and steel are least liable to a change of magnetic intensity under moderate fluctuations of temperature.

Specimens of steels containing severally tungsten, manganese, cobalt, and nickel, also cast irons, of different blends of pig irons, and

of different percentages of carbon, were procured from a number of different English and Scotch firms. The size of these specimens was in general about 15 cm. long and 1 or 2 thick, but as it was not uniform the dimensions and weight in grams of each are given in the accompanying table, columns I, II, and III.

In column IV has been entered the dimension ratio, *i.e.*, the ratio of the length to the diameter or breadth, so that a comparison may more consistently be made of the magnetic behaviour of any two specimens. For thin rods, Cancani* finds that increase of this ratio tends to diminish the temperature coefficient of a magnet.

The course of an experiment was as follows:—The rod or bar in its normal state, or after being hardened or annealed as occasion required, was magnetised between the poles of a powerful electro-magnet excited by a battery of twenty-six storage cells. The magnet was then fixed rigidly in a horizontal tube, through which a stream of cold water and steam could be alternately passed. The tube and its contents were placed at a convenient distance from a sensitive dead-beat magnetometer and at right angles to the magnetic meridian. The deflections of the magnetometer needle were read by the usual mirror and scale, the distance of the scale from the mirror being 1 metre, and from the readings were deduced directly the temperature coefficient and the total irreversible loss of magnetism. As the deflections were never more than a few degrees of arc the angles and their tangents were virtually equivalent. The intensity of magnetisation in C.G.S. units or magnetic moment per unit volume, although not necessarily required, was approximately determined from the formula

$$\mathrm{I} = \mathrm{H}\frac{(d^2-l^2)^2}{2d}\tan\theta\,\frac{\sigma}{m},$$

in which the earth's horizontal force, H, was considered throughout as constant and equal to 0·18 C.G.S. unit and also σ, the density, was uniformly taken to be 7·8; m signifies the mass in grams; d the distance from the centre of the magnet to the magnetometer needle; l the half length of the magnet, and θ the deflection.

The process of heating and cooling the magnet was continued until the intensity fluctuated between two nearly constant values corresponding to the temperatures of the cold water and steam. The coefficient α given in the eighth column was then calculated by inserting these values in the equation

$$\mathrm{I}_{t'} = \mathrm{I}_t\,(1-\alpha\,\overline{t'-t}).\dagger$$

* R. Cancani, 'Atti della R. Acc. dei Lincei,' (4), 3, pp. 501—506, 1887; 'Beibl.,' vol. 11, 1887.

† I have followed the customary mode of writing this formula with a negative sign preceding the coefficient, α; and, hence, a *negative coefficient* indicates an *increase* of magnetic intensity with *increase* of temperature.

The irreversible loss of original magnetic intensity which results from a series of heatings and coolings is tabulated under the heading β in column VII, β being calculated from the formula

$$I_f = I_i (1-\beta),$$

where I_f and I_i are the final and initial intensities.

The limits of temperature t and t' in these experiments were 10° to 20° C. and about 100° C., giving a range of 80° or 90°.

The centigrade scale of temperatures and the C.G.S. system of units are to be understood throughout.

In every case a record has been kept of the scale readings at the temperatures t and t' during the progress of the operations of heating and cooling, and the brief example here cited may be taken as typical.

Three per cent. Tungsten Steel.

Temperature.	Scale readings at t.	Scale readings at t'.	Zero 0·0
6·5	184·8		
99·6	..	142·6	
7·5	161·3		
99·6	..	140·2	
7·5	160·2		
99·6	..	137·9	
7·5	158·8		
99·6	..	137·9	
7·5	158·6		Zero −0·1

The table which is annexed gives a synopsis of the results obtained.

Each number in the first column represents a separate piece of iron or steel, but where comparative tests of the same material were desired, as, for example, in the cast irons, when either annealed or hardened, the precaution was taken to employ two pieces of originally a single rod. Thus Nos. 15 and 16 are two parts of the same rod cut through the middle, and similarly with Nos. 17 and 18 and others.

In the first place, several varieties of steels were tested. No. 1 is a steel from Sheffield, supplied specially for making magnets; Nos. 2 and 3 are Hadfield's well-known non-magnetic steel; the next four are tungsten steels, of which Nos. 6 and 7 are known as Mushet's self-hardening steel, having the property of hardening even when cooled slowly. These were both cut from the same rod; No. 6 was

Table I.

No.	Specimen.	Condition.	I. 2*l*.	II.* *d*.	III. *m*.	IV. R=2*l*/*d*.	V. I_i.	VI. I_f.	VII. β.	VIII. α 0·00.	
1	"Magnet" steel.	Hardened	15·9	2·0	366	8·0	53·2	40·6	0·237	+137	From Sheffield.
2	*Manganese* steel.	,,	15·2	2·4	532	6·3	0·75	0·63	0·150	+031	Do.
3	,,	Annealed	15·1	2·3	520	6·5	0·30	0·257	0·150	+045	Do.
4	*Tungsten* steel...	Hardened	16·0	2·6(*s*)	855	*6·1*	39·7	34·1	0·142	+142	W = 3 p. c. C = 0·6 to 1·0 p. c. From Sheffield.
5	,,	,,	16·0	2·7(*s*)	856	*5·9*	69·8	50·3	0·280	+025	W = 6·1 p. c. C = 2·1 p. c. Mn = 1·8 p. c. Cr = 0·5 p. c. Si=0·5 p. c. From Sheffield.
6	,,	,,	11·9	0·97	65	12·0	185·9	132·6	0·287	+069	Mushet's self-hardening steel. Do.
7	,,	,,	16·5	0·97	92	17·0	215·3	177·8	0·174	+097	Do. Do.
8	*Cobalt* steel.....	,,	10·8	3·14	650	3·4	16·4	12·8	0·217	+115	Co = 4·5 p. c. C = 0·5 p. c. Do.
9	*Nickel* steel.....	,,	16·0	2·5(*s*)	777	*6·4*	28·7	24·1	0·160	+025	Ni = 3 p. c. C = 0·45 p. c. Do.
10	,,	As supplied	20·3	1·95	480	10·4	16·7	12·6	0·244	+200	Ni = 2·4 p. c. C = 0·19 p. c. Scotch.
11	,,	Hardened	20·3	1·95	480	10·4	128·0	109·4	0·145	+032	
12	,,	,,	15·7	1·6(*s*)	331	*9·8*	79·8	35·7	0·526	−017	Ni = 3 p. c. C about 0·22 p. c. Do.
	,,	Annealed	,,	,,	,,	,,	106·4	66·1	0·303	+024	
	,,	Hardened	,,	,,	,,	,,	111·7	55·9	0·500	−018	
13	,,	,,	16·0	1·4(*s*)	247	*11·4*	0·54	0·42	0·225	−054	Ni = 27 p. c. C about 0·27 p. c. Do.
14	,,	,,	16·3	1·3(*s*)	242	*12·5*	0·54	0·45	0·169	−005	
15	*Cast iron*.......	As supplied	17·5	1·35	175	13·0	52·1	37·6	0·279	+288	Dalmellington, Yorkshire, and scrap irons.
16	,,	Hardened	16·0	1·35	160	11·8	193·1	167·8	0·131	+018	
17	,,	As supplied	15·3	1·17	113	13·1	59·5	37·2	0·374	+272	Glengarnoch, and scrap irons.
18	,,	Hardened	15·3	1·17	111	13·1	210·9	180·1	0·146	+016	
19	,,	As supplied	15·3	1·17	113	13·1	56·9	35·6	0·374	+242	Scotch, white, and scrap irons.
20	,,	Hardened	15·2	1·17	112	13·0	190·6	174·8	0·083	+016	
21	,,	As supplied	12·8	0·98	65	13·0	27·3	26·3	0·038	+053	Carbon over 5 per cent.
22	,,	Hardened	12·0	0·96	59	12·5	31·1	27·9	0·104	+029	
23	,,	,,	13·6	2·52	473	5·4	5·0	4·6	0·074	+054	

* (*s*) signifies that the cross section of the specimen is square; the dimensional ratio of such is figured in *italics*. All others had a circular cross section.

magnetised at the air temperature; No. 7 was made red hot and allowed to cool whilst in the magnetic field. No. 8, a specimen of cobalt steel, was kindly supplied by Mr. Hadfield, and is probably unique. All of these and the first example of nickel steel, No. 9 on the list, are Sheffield steels.

Attention was then directed chiefly to three classes: Nickel steels, cast irons, and steel pianoforte wires.

Nickel Steels.—The first of these, No. 9, is a crucible steel from Sheffield, containing 3 per cent. of nickel and about 0·45 per cent. of carbon. The next two are from Scotland. They contain 2·4 per cent. of nickel and 0·19 per cent. of carbon. Nos. 12, 13, and 14 are also from Scotland, and contain 3 per cent. and 27 per cent. of nickel. They were kindly supplied by Mr. Riley, of the Glasgow Iron and Steel Company. The behaviour of the last three was remarkable, as when hardened they exhibited a small, *negative* coefficient. On heating and cooling they continuously lost magnetism for the first three alternations; at the fourth and fifth heating and cooling there was hardly any change of intensity; afterwards a small increase of intensity with rise of temperature and decrease with fall of temperature regularly took place. In the specimen containing 3 per cent. of nickel these operations caused a total loss of no less than 50 per cent. of the original magnetic intensity. This same piece was then annealed and magnetised; the coefficient was now *positive*, the intensity rather higher, and the total loss 30 per cent. On rehardening the events first described were reproduced, the negative coefficient and large total loss being almost exactly as before. It is very likely that by carefully adjusting the degree of hardness in this kind of steel a zero coefficient could be obtained.

The 27 per cent. nickel alloys, after hardening in cold water, became almost non-magnetic, as discovered by Dr. John Hopkinson,* and it was only in this state that they were tested. No. 13 was magnetised at the air temperature; No. 14 at $-16°$. All the other examples of nickel steels had positive coefficients.

Cast Irons.—Specimens of grey cast iron, as used for general castings made at different times and of different blends of pig irons behaved very similarly. Magnetised as supplied they did not take a high intensity, lost permanently 30 to 40 per cent. of their magnetism, and had a large temperature coefficient. When hardened their magnetic properties were very different; the intensity was then comparable with that of tungsten steel, the total loss only about 15 per cent., and the temperature coefficient as low as, or lower than, the best examples of hardened steels. In three different kinds of carefully hardened cast-iron magnets it was from 0·00016 to 0·00018 per degree centigrade. The average value for steel magnets of a similar

* Hopkinson, 'Roy. Soc. Proc.,' vol. 48, p. 61.

size tested at the Kew Observatory is given by Whipple as 0·00029.* The change of intensity with temperature is almost strictly linear in these cast-iron magnets, and they are very constant when subjected to blows and shocks.

Pianoforte Wire.—Lengths of 12 cm. each were cut from a coil of wire, and tested after various treatments. Magnetised in the normal state this material unexpectedly gave a *negative* coefficient. When heated to bright redness and chilled rapidly or slowly the coefficient became positive.

As it was thus possible to change the sign of the coefficient, an attempt was made to find the particular temper which would give a zero coefficient. Lengths of the wire were heated severally in oil to 200° and 260°, and in air to a temperature producing a film of oxide, and rapidly chilled in water. The coefficient still remained negative, and of nearly the same magnitude. But when heated to dull redness and quenched, the coefficient was very nearly reduced to zero. Heated to higher temperatures and quenched, the coefficient became positive.

Table II.

No.	Condition.	$R = 2l/d$.	I_i.	I_f.	β.	$\propto$ 0·00.
16*a*	As supplied	109	649·0	644·6	0·008	−0·023
	Tempered at 260°..	,,	792·1	769·2	0·029	−0·018
	Ditto dull red	,,	883·0	863·6	0·022	−0·002
	Ditto, ditto.......	,,	892·0	869·0	0·026	+0·003
	Glass hard	,,	559·5	537·1	0·040	+0·008
	Annealed.........	,,	849·0	830·1	0·023	+0·006
16*b*	As supplied.......	100	679·0	633·6	0·067	−0·055
	Glass hard	,,	593·0	497·0	0·163	−0·017

Length of each piece, 12 cm.; weight, about 0·9 gram; diameter, 16*a* = 0·11 cm., 16*b* = 0·12 cm. These two specimens are made from different kinds of steel.

It is a curious coincidence that the intensity of magnetisation attains a maximum for the condition producing minimum temperature coefficient, and this maximum has the exceptionally high value of 892 C.G.S. units.

The fact that the negative coefficient could not be reproduced if once the wire had been heated above a red-heat indicates that there is some structure physically imposed upon music wire, perhaps in the process of drawing, which partly or wholly contributes in producing the negative coefficient. Whereas the negative coefficient in the nickel steel is reproducible, and is doubtless a consequence of

* Whipple, 'Roy. Soc. Proc.,' vol. 26, p. 218.

intense hardness. In contrast with this it may be mentioned that music wires are not at all hard, being easily touched with a file.

In order to gain further insight into the cause of the negative coefficient in these wires, some experiments were made to test the effect of removing successively the outer layers of the wires by dissolving them in nitric acid. This revealed the important relation that the coefficient became more negative as the diameter became less, the length remaining the same, that is to say, as the dimension ratio increased.

To verify this carefully a series of stout music wires of different thicknesses, but in other respects as uniform as possible, were procured from a manufacturer at Warrington, to whom I am also indebted for kindly supplying other samples of steel wire. The results of these experiments are most conveniently exhibited in tabular form, and are here annexed.

Table III.

No.	d.	m.	R.	I_i.	I_f.	β.	α. 0·00	$\alpha \times d$. 0·0000
33	0·216	3·535	55·3	530·3	428·5	0·192	−0136	294
30	0·187	2·590	63·8	592·8	508·6	0·142	−0184	344
28	0·174	2·235	69·0	632·4	551·5	0·128	−0226	393
26	0·153	1·760	78·0	736·0	652·8	0·113	−0203	310
24	0·134	1·365	89·0	742·0	686·3	0·075	−0306	410

Length of each piece = 12 cm.

With the exception of No. 26 (and No. 26 was anomalous in some other respects) the coefficients become progressively more negative as the dimension ratio increases. The increasing product of the coefficient into the diameter shows that the coefficient changes more rapidly than the dimension ratio. The table also shows the regular diminution of the permanent loss, β, and increase of intensity as the dimension ratio increases, relations which hold in further experiments of the same kind to be described later on.

Several of these wires after being thus tested were dissolved in nitric acid, and the temperature coefficient determined at successive stages of the process without any remagnetisation of the wire. The results of No. 33 alone are here given, as they sufficiently exemplify what generally takes place under these circumstances. The negative character of the coefficient progresively increases with increase of dimension ratio, and at a rather greater rate as in Table III.

It is interesting to observe in these experiments the increase of

Table IV.

No.		d.	m.	R.	I_i.	I_f.	β.	α 0·00.	$\alpha \times d$. 0·0000.
	33	0·216	3·535	55·3	530·3	428·5	0·192	−0·0136	294
Dissolved.	1st stage	0·195*	2·875	61·3	478·0	464·6	0·028	−0·0155	302
	2nd stage	0·163*	1·995	73·6	474·5	468·9	0·012	−0·0196	319
	3rd stage	0·112*	0·935	107·5	485·5	482·9	0·005	−0·0292	327

intensity each time the wire is redissolved, remembering that after the initial magnetisation the wire was *not subjected to any further magnetising process.* Thus, for example, No. 33 has an intensity, after being heated and cooled, of 428; upon dissolving off an outer layer the intensity rises to 478, which in its turn is reduced by heatings and coolings to 465; dissolving it a second time raises the intensity to 475, and so on. The recovery of magnetic intensity after dissolving in acid is most likely to be ascribed to diminution of the self-demagnetising force resulting from increase of dimension ratio. The intensities, however, after each dissolving, namely 478, 475, 486, are sufficiently constant to indicate that the intensity is nearly uniform throughout the wire, and this confirms an experiment of Bouty's.†

The next two wires have been grouped in a separate table from the others, as they came from a different factory, being made in Sheffield. They are thicker than the former wires, and the thicker of the two, No. 34, has now a *positive* coefficient. By continually reducing the diameter of this wire, the coefficient ultimately changes sign and becomes *negative.*

Table V.

No.		d.	m.	R.	I_i.	I_f.	β.	α. 0·00.
	32	0·227	3·875	52·8	490·1	340·6	0·305	−0·0015
	34	0·262	5·145	45·8	388·6	271·9	0·304	+0·0220
Dissolved.	1st stage ...	0·223‡	3·740	53·7	307·2	299·2	0·026	+0·0193
	2nd stage ..	0·204‡	3·130	58·7	297·9	290·3	0·025	+0·0184
	3rd stage ..	0·152‡	1·742	78·8	306·6	300·2	0·021	+0·0082
	4th stage ..	0·075‡	0·427	159·2	292·5	287·1	0·019	−0·0100

Length, 12 cm.

* Calculated from the weight.

† 'Ann. Scient. de l'Éc. Norm.,' [2], 5, p. 131.

‡ Calculated from the weight.

And it may be calculated that if No. 34 had just been dissolved so far as to have a dimension ratio of about 110 to 115, it would have exhibited a zero coefficient. Since the former series of wires with dimension ratios of this magnitude would have had large negative coefficients, there must be some important physical or chemical differences between these and the former wires influencing the character of the coefficient.

To complete the series of experiments on the influence of the dimension ratio it was desirable to perform the converse operation and to prove that an originally negative coefficient would become positive by increase of thickness.

Three pieces, (*a*), (*b*), (*c*), of No. 33 wire were cut from the same coil, each 12 cm. long, magnetised and then heated and cooled separately in the same way. The coefficient was about −0·000119 for each. (*a*) and (*b*) were then bound together with fine copper wire, like poles being in contiguity; the coefficient as now determined was almost zero. The piece (*c*) was then joined in the same manner to its two fellows and the coefficient again determined; it was now + 0·000105. The experiment is conclusive, for it is allowable to regard bundles of wires as rods of equivalent cross section.*

Wires drawn to different thicknesses are not structurally sufficiently identical to allow of strictly comparable magnetic results. It is therefore more satisfactory to vary the dimension ratio by altering the length and keeping the diameter constant. A series of tests were conducted in this way. Lengths of 3, 6, 9, 12, 15, and 18 cm. of No. 30 wire were cut from the same coil, separately magnetised, and the coefficient of each very carefully determined. Table VI gives a complete view of the results.

Table VI.

No.	$2l$.	R.	Ii.	f.	β.	α. 0·00.
30	3 cm.	15·95	137·4	78·7	0·427	+0261
,,	6 ,,	31·90	313·4	204·0	0·349	+0151
,,	9 ,,	47·85	483·2	378·3	0·217	−0084
,,	12 ,,	63·80	602·0	513·8	0·147	−0225
,,	15 ,,	79·75	683·1	595·0	0·129	−0296
,,	18 ,,	95·70	726·8	637·4	0·123	−0317

Diameter of each piece, 0·187 cm.

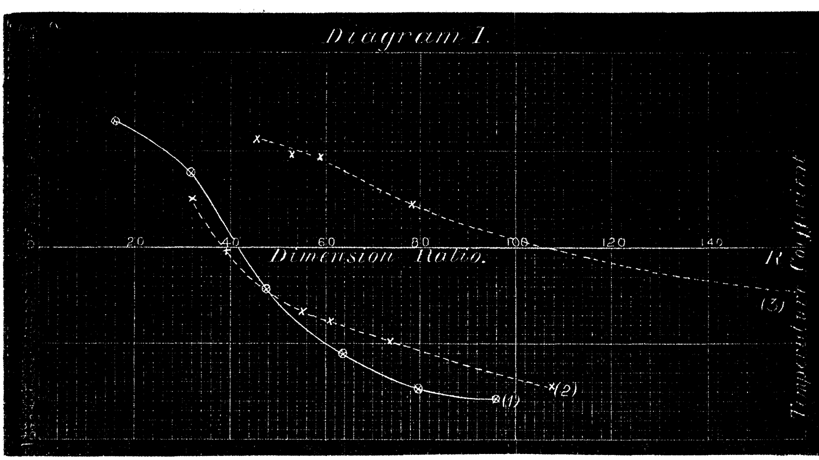
* Von Waltenhofen, 'Wien. Ber.,' vol. 48, part 2, p. 578, 1863. Ascoli and Lori, 'R. Accad. dei Lincei,' Rome (5), 3, 2 Sem., p. 157, 1894.

The coefficient changes from positive to negative between the lengths 6 and 9 cm. And hence if the change between these points is nearly linear, a length of about 8 cm. should have a zero coefficient, and it might also be calculated that the permanent loss would be 0·262. A fresh length of exactly 8 cm. was cut from the same coil of wire and was found to have a coefficient of −0·000015, and a permanent loss of 0·281. A piece of this wire, a very little less than 8 cm. long, would without doubt, have a strictly zero coefficient.

There are thus two practicable ways of obtaining zero temperature coefficients, either (1) by altering the hardness, or (2) by altering the dimension ratio; and the latter may be effected by varying the diameter for a constant length, or the length for a constant diameter as may be the more convenient. In addition, the material of which the magnet is made must have certain chemical and physical properties, not yet determined, of which, as far as some experiments I have made can decide, the physical rather than the chemical properties are the more important.

Some of the results in Tables IV, V, and VI are here plotted as curves and exhibit interesting features.

The curve of the relation of coefficient to dimension ratio (diameter constant) from the data of Table VI, Diagram I, curve (1), has a double inflexion between which it crosses the axis of abscissæ and



at either end apparently approaches to horizontal asymptotes. This curve is probably typical of the behaviour of music wires.

Curve (2) on this diagram traces the series of experiments on No. 33 wire. The two first points on the left correspond to the

coefficients for three and two pieces bound together, the third point that for a single piece, and succeeding points the coefficients for the same piece at three stages of dissolution. The third curve is constructed from the data in Table V, and represents the passage from a positive to a negative coefficient in No. 34 wire.

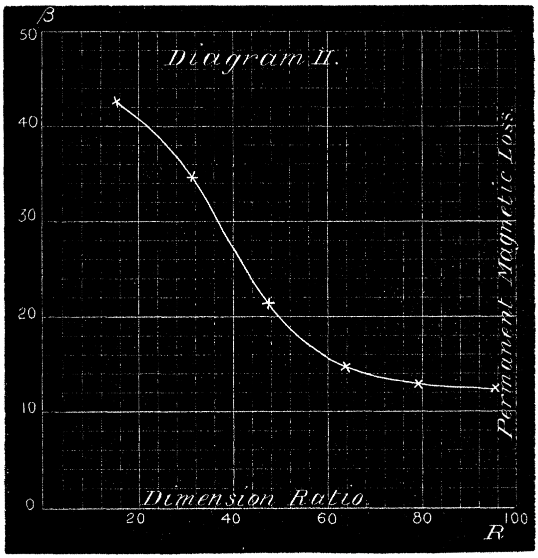


Diagram II exhibits the curve of permanent loss, β, and dimension ratio, R, taken from Table VI for No. 30 wire, diameter constant, and it will be seen it follows remarkably closely the path of the coefficient curve. The coefficient, α, and the permanent loss, β, may then be connected by a linear equation

$$\alpha = a + b\beta.$$

The values of the constants for this material are

$$a = -0{\cdot}0005228 \pm 0{\cdot}0000073 \text{ and}$$

$$b = +0{\cdot}001886 \pm 0{\cdot}000043.$$

If curves for α and β be plotted with demagnetising factors, *i.e.*, the demagnetising force per unit intensity, corresponding to their dimension ratios as abscissæ they resemble, strikingly, curves of magnetisation, having a point of inflection near the beginning and ultimately approaching horizontal asymptotes (Diagram III); by prolonging the curves in this diagram until they cut the axis of

ordinates it is easy to estimate what may be called the "characteristic" temperature coefficient and permanent loss for this kind of wire.

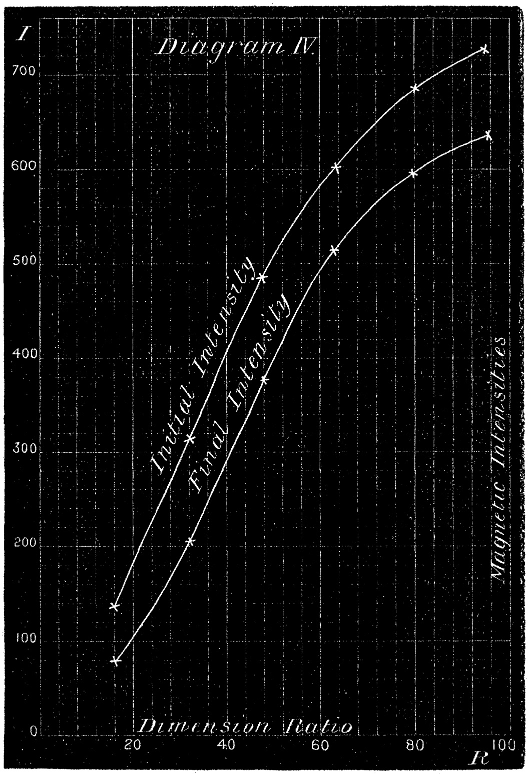
It may be inferred that in general the temperature effects upon magnets are principally influenced by the demagnetising factor over a considerable range of dimension ratios, and beyond that range by the nature of the material.

In the fourth diagram the curves of initial and final intensities are plotted with dimension ratios as abscissæ, and they resemble so closely the curve traced in the same way by Barus* for steel of "blue annealed" temper, that it is very probable this is the temper given to the music wires upon which these experiments have been made.

The chief points elicited by this investigation may now be summarised:—

1. The temperature coefficient is generally least in the hardest

* Barus and Stronhal, 'Bulletin U.S. Geol. Survey,' No. 14, 1885.



irons and steels, and is particularly small in hardened cast iron. Certain hardened nickel steels have very small negative coefficients.

2. The discovery of negative coefficients in music wires.

3. Change of the sign of the coefficient by alteration of (*a*) temper and (*b*) dimension ratio, and hence methods of obtaining zero coefficients.

4. Some relations between the dimension ratio and self-demagnetising factor, temperature coefficient, and permanent loss of magnetism after alternate heatings and coolings.

An important consideration in any practical application to magnetic instruments of magnets with zero coefficients is the constancy of the zero state.

It is not yet possible to speak precisely on this point, but two wires which had been prepared by adjustment of temper to have zero coefficients in June, 1896, and since then had been lying on a shelf, and in the vicinity of other magnets, when tested nine months later, had not altered so much as to have a coefficient of practical

consequence. The intensity had diminished, however, by nearly 25 per cent.

Similarly the magnet which had been given a negligible coefficient by cutting the length of the wire to 8 cm., as cited above (p. 219), after being boiled at intervals for four hours, was found five months later to have changed so little that its coefficient might still be considered negligible.

Further experiments, however, upon this question and some others arising out of this investigation are now in progress.

"The Electric Conductivity of Nitric Acid." By V. H. VELEY, M.A., F.R.S., and J. J. MANLEY, Daubeny Curator of the Magdalen College Laboratory, Oxford. Received November 1,—Read December 9, 1897.

(Abstract.)

In this paper an account is given of determinations of the electric conductivity of nitric acid of percentage concentrations varying from 1·3 to 99·97, purified, so far as possible, from reduction products of the acid, as also from sulphuric and the halogen acids, with which it is likely to be contaminated from its process of manufacture. In the preliminary experiments it was observed that the results might be vitiated by (i) a trace of nitrous acid either directly added or produced by decomposition due to exposure to sunlight, and (ii) imperfect insulation of the electrolytic cell caused by metallic clamps, a point which seems to have been neglected by previous observers.

The methods adopted for the purification of the water and nitric acid, as also for the detection and estimation of the impurities, are described in full. The greatest quantity of nitrous acid, sulphuric acid, and the halogen acids found in any sample used were 0·75, 4·3, and 3·8 parts per million respectively.

The thermometers, resistance coils, and other instruments used were compared with certain standards and corrected accordingly; the burettes and electrolytic cells were calibrated by one or more methods, and the mean of the values accepted.

The method adopted for the determinations was in outline that originally described by Kohlrausch, but modified so as to overcome certain difficulties experienced. A particular form of bridge was constructed, in which the wire was an air line, and a special form of slider adopted to tap without sagging the wire, so arranged that it could be moved by the observer from the extremity of the bridge, and thus all thermo-currents due to his proximity were avoided.

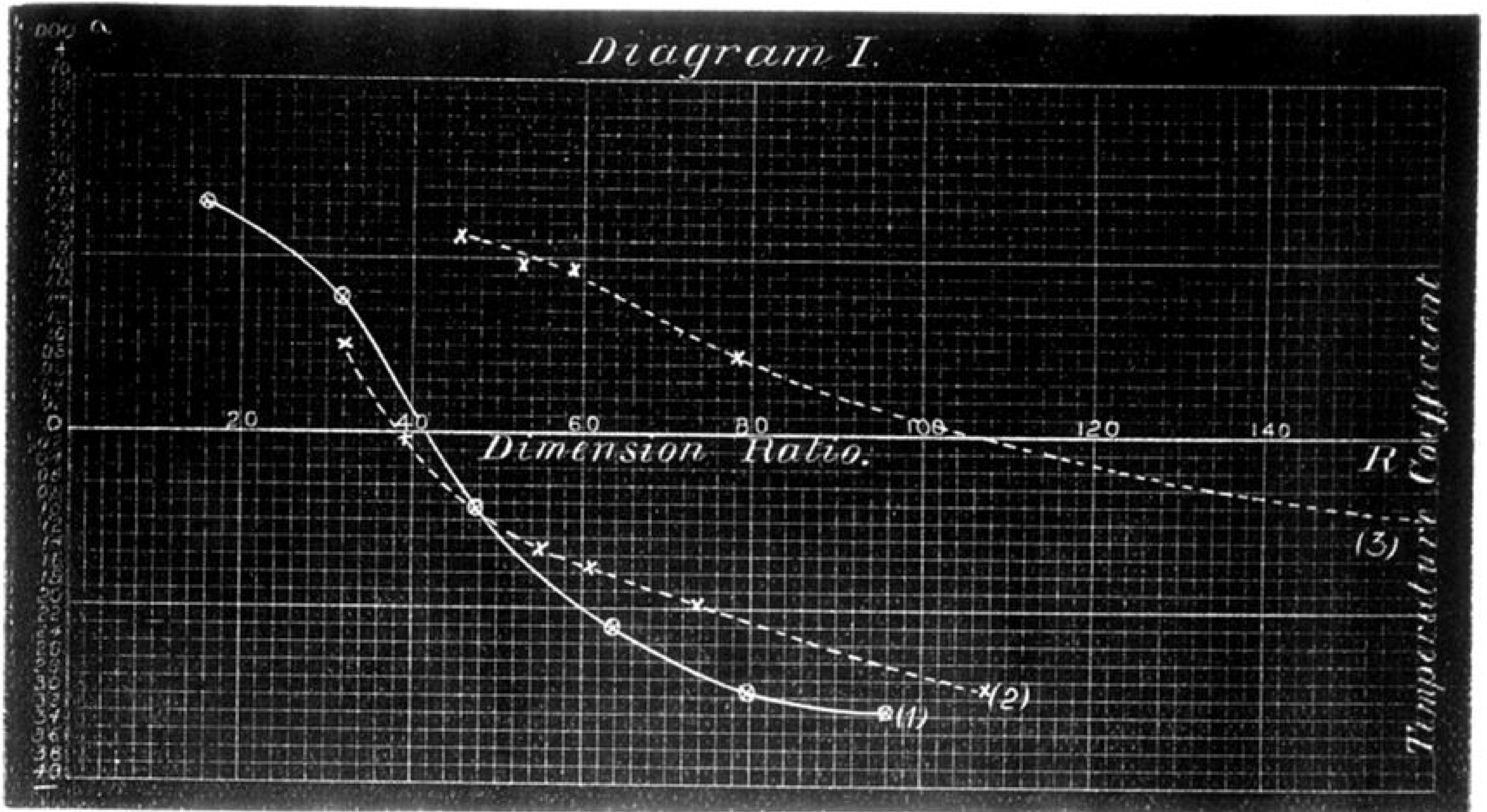


Diagram I.
Dimension Ratio.
20
40
60
80
100
120
140
R
0
(1)
(2)
(3)
Temperature Coefficient

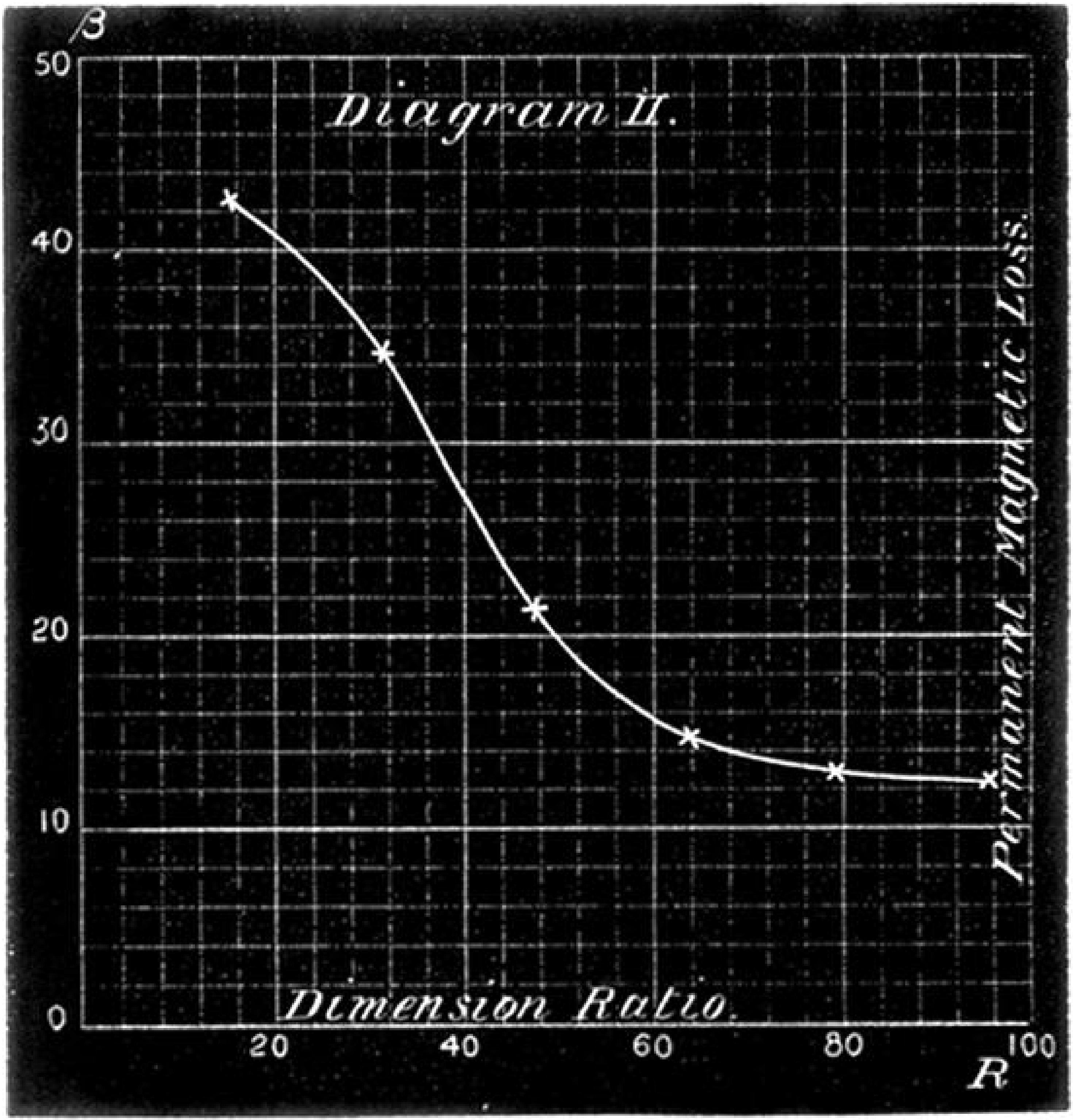


Diagram II.
β
50
40
30
20
10
0
20
40
60
80
100
R
Dimension Ratio.
Permanent Magnetic Loss.

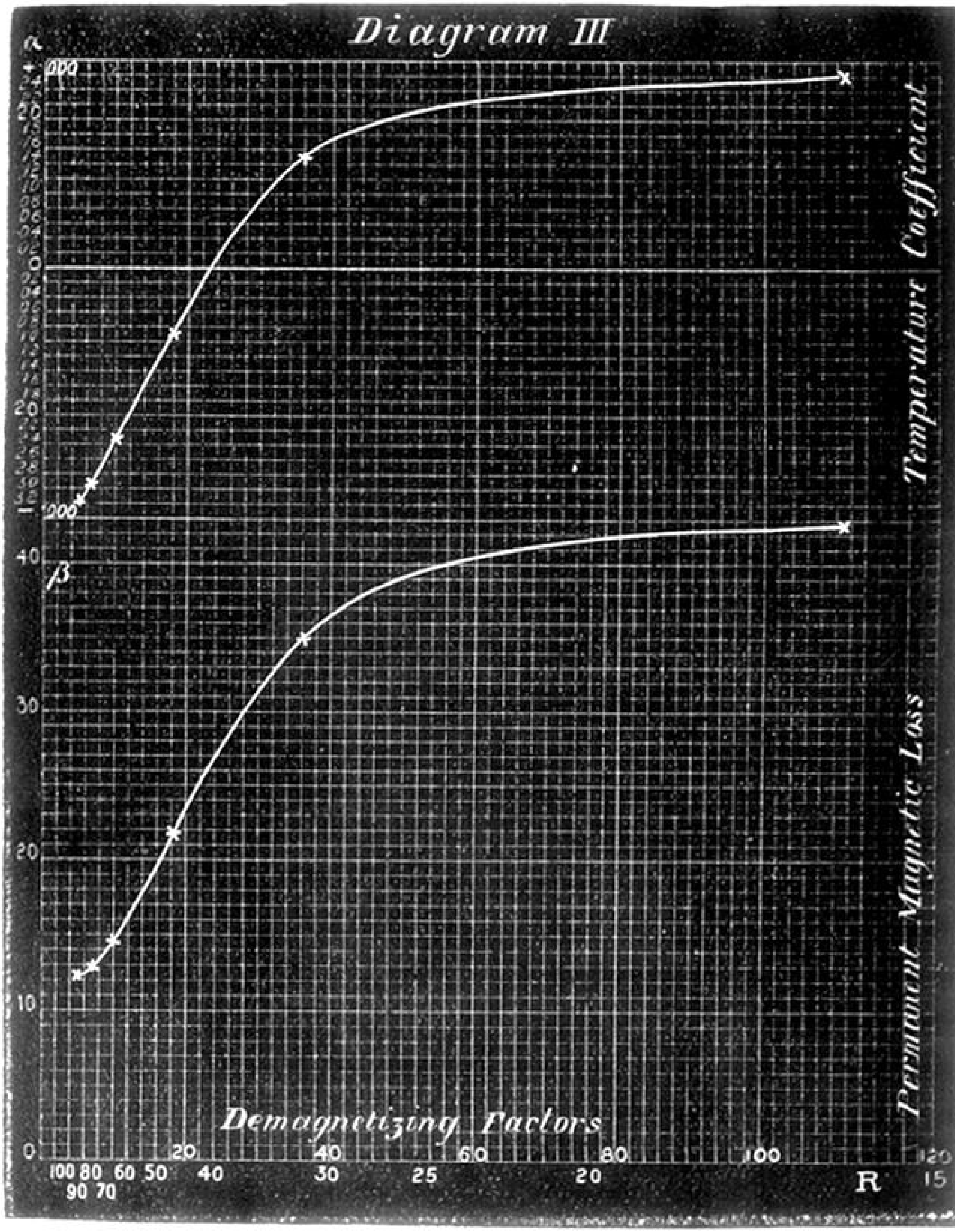
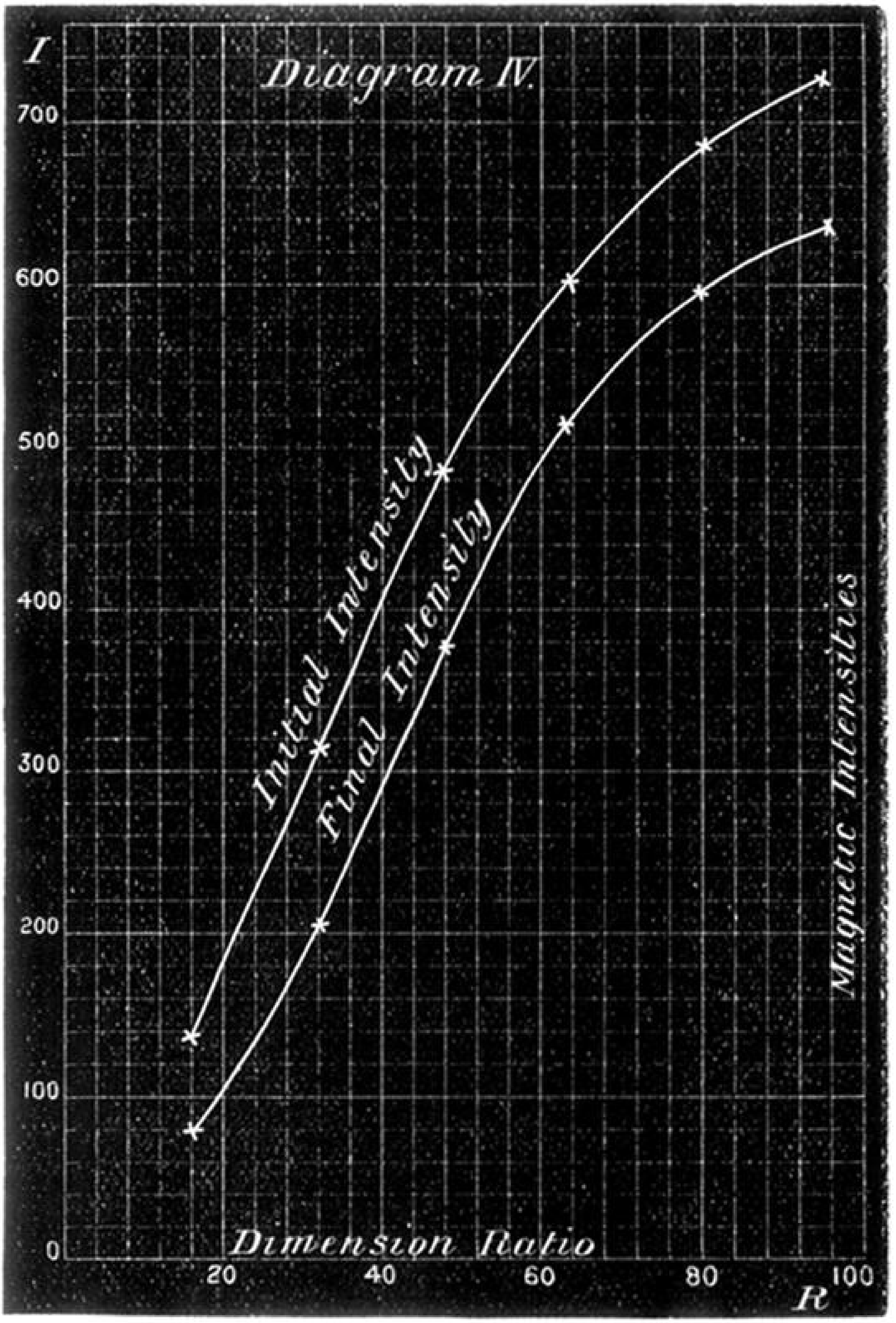


Diagram III
Temperature Coefficient
Permanent Magnetic Loss
Demagnetizing Factors
α
β
R


I
Diagram IV.
700
600
500
400
300
200
100
0
Initial Intensity
Final Intensity
Magnetic Intensities
Dimension Ratio
20
40
60
80
100
R